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RESEARCH FOR CLEAN WATER

ROBERT A. TAFT SANITARY ENGINEERING CENTER
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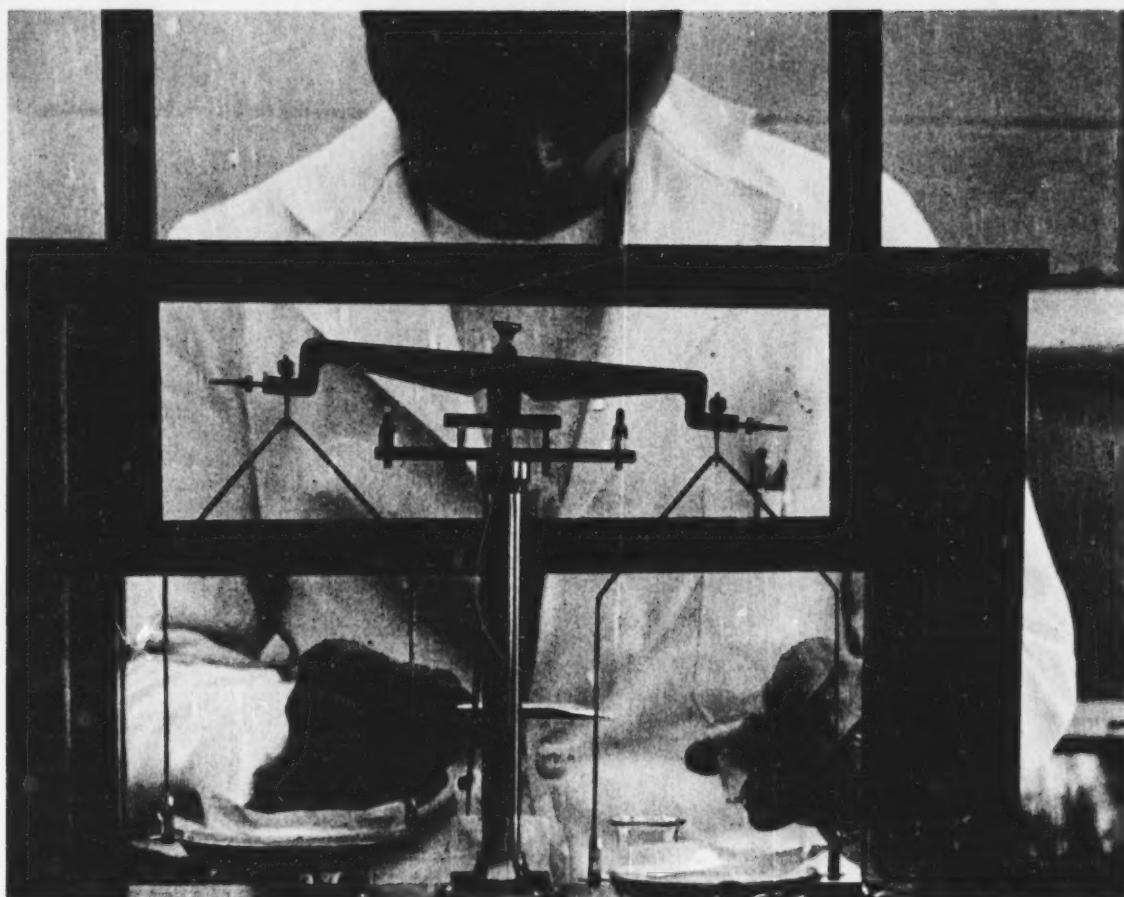
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U. S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE Public Health Service

41



Preparing media for fungi culture.

The Secretary shall conduct in the Department of Health, Education, and Welfare and encourage, cooperate with, and render assistance to other appropriate public (whether Federal, State, interstate, or local) authorities, agencies, and institutions, private agencies and institutions, and individuals in the conduct of, and promote the coordination of, research, investigations, experiments, demonstrations, and studies relating to the causes, control, and prevention of water pollution. In carrying out the foregoing, the Secretary is authorized to...

(1) collect and make available, through publications and other appropriate means, the results of and other information as to research, investigations, and demonstrations relating to the prevention and control of water pollution, including appropriate recommendations in connection therewith;

(2) make grants-in-aid to public or private agencies and institutions and to individuals for research or training projects and for demonstrations, and provide for the conduct of research, training, and demonstrations by contract with public or private agencies and institutions and with individuals without regard to sections 3643 and 3709 of the Revised Statutes;

(3) secure, from time to time and for such periods as he deems advisable, the assistance and advice of experts, scholars, and consultants as authorized by section 15 of the Administrative Expenses Act of 1946 (5 U. S. C. 55a)...

From Section 4, Federal Water Pollution Control Act

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The Center.

Research for Clean Water

A report on activities of the Research Branch,
Division of Water Supply and Pollution Control, at
the Robert A. Taft Sanitary Engineering Center,
Cincinnati, Ohio.

U. S. DEPARTMENT OF HEALTH,
EDUCATION, AND WELFARE

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Cover:

Forest Landscape

Cornelius Ploos Van Amstel

Dutch. 1726-1798

Bequest of Herbert Greer French
The Cincinnati Art Museum

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The last few years have witnessed an acceleration of research on water resources in the United States. The national effort to improve the technology of managing water quality has been stimulated in particular by recent legislation expanding Public Health Service programs of research in water supply and pollution control. This effort will undoubtedly be broadened as university and industrial laboratories increasingly undertake work in this field. More than ever before, therefore, there is a need for an understanding of the nature of the water quality problem confronting us and for information on the directions research must take in solving these problems.

As in an earlier publication, this report describes the major research projects of the Research Branch. In addition, a listing of technical publications of the last two years is included. The level and duration of effort on each of the projects are given in terms of man-years of effort expended.

There is strong justification for assuming that the current activity in research will expand internationally in the future. Beyond the effort in this country, there is already clear evidence that other industrially advanced nations will undertake research directed to problems of the type confronting us in the United States. The need for the development of effective lines of communication with research agencies of other nations is being expressed with increased frequency. It is believed that this research brochure will be of value to all agencies engaged in or proposing to engage in the field of water quality research.



Cooking fish for taste and odor assay.

WASTE CHARACTERIZATION

The nature of the contaminants in our water resources has become increasingly important to the welfare of this country since its first settlement. Today researchers at the Center examine the importance of these contaminants according to a system of waste characterization. This is the scientific process of learning how much harm a particular waste will cause. What will its effect be on water and sewage treatment operations, on aquatic life, on the taste and smell of drinking water? One traditional characterization test is the biochemical oxygen demand examination (BOD). It expresses the amount of dissolved oxygen required by microbes and chemical reactions in the stream which destroy much of the organic matter in the waste. The oxygen consumed in this way is, of course, no longer available to fish and other oxygen-dependent life. A waste with a high BOD may cause oxygen loss great enough to produce an extensive fish kill and the death of other important aquatic life.

The wastes with which we are most familiar are relatively simple and their BOD is a fairly accurate measure of their pollutional effects. However, modern industrial and community wastes, with space-age chemicals and compounds, contain many pollutants not shown by the BOD test. Learning the significance of these newer pollutants is the task of the waste characterization projects described in the following pages.



Tasting test fish.

FORECASTING THE EFFECTS OF NEW POLLUTANTS

The vastness and complexity of waste products being dumped daily into our nation's water resources have made traditional methods of measuring and controlling water pollution less useful and created the need for new ones.

More than 10,000 synthetic organic chemical products, each a potential water pollutant, are marketed in the U. S. today and the number is increasing rapidly. A myriad of additional industrial pollutants produced as side reactions in manufacturing processes are discarded. The chemical identity of many of these waste products is never determined and very little is known about the pollution effects of any of them. These new chemicals also are a problem in domestic sewage. Standardized measurements do not provide adequate information for evaluating the harm these wastes can do in water resources.

Clearly, a pollution control program based on eliminating specific waste compounds or keeping them below dangerous levels cannot work well because of the immense number of unknowns and the difficulties of analysis. The Center is meeting this problem by developing means of measuring the damaging effects of industrial wastes directly without immediate concern as to the specific compounds or groups of compounds responsible for the harmful results.

One example of such a measurement is the fish bioassay technique for determining waste toxicity to fish. Here, fish are subjected to varying concentration levels of waste and the necessary dilution permitting them to survive is arrived at. Similar procedures have been developed for estimating most other damaging effects including tastes, odors, treatment problems, etc. These new techniques are being demonstrated and their use promoted. They also should be improved and still other similar methods devised.

One project demonstrating these new methods has been completed. Wastes from the catalytic cracking of petroleum, an important recurrent process waste, were used for the demonstration. Results of this project will soon be published.

Two other such projects are underway: (1) the characterization of water polluted by outboard exhausts and (2) determination of the effect of oil-emulsion wastes from metal finishing operations on various sewage treatment processes.

THE HEALTH THREAT OF IMPURE WATER

Three main aspects of water quality pose an increasing threat to the public health: (1) industrial organic wastes, (2) man-made changes in the inorganic balance and (3) feces-borne viruses.



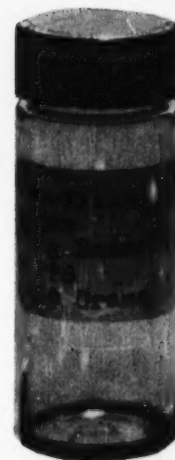
Post-mortem on fish killed by pollution.

What significance today's chemical impurities in water have on public health is unknown. If harmful effects are found, they are sure to be widespread. Such wastes are increasing rapidly in amount and complexity. Household detergents are now a normal component of domestic wastes. There are industrial wastes from synthetic organic chemical plants. Pesticides and other strong agricultural chemicals are reaching more and more waterways from farm land drainage.

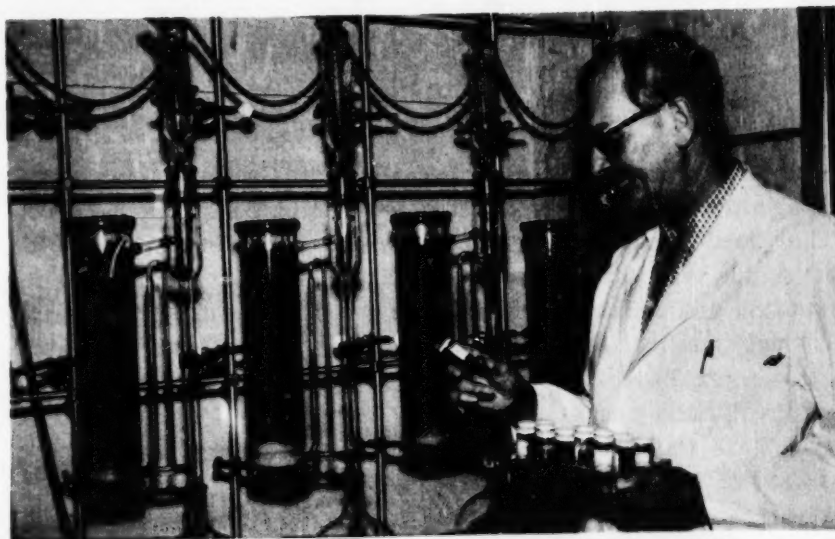
What effects will inorganic impurities have on national health? Public Health Service drinking water standards have undergone a recent revision in an attempt to consider these impurities. Recent reports of increased cardiovascular death rates in cities with soft water have attracted additional attention to this facet of water quality.

The association of infectious hepatitis, a feces-borne virus, with water supplies greatly concerns public health officials. An epidemic of this disease in New Delhi, India in 1956 and 1957 has indicated conventional water purification methods may not always protect the consumer from this disease. The National Research Council has recently raised questions about the relationship between the turbidity of municipal water supplies and the incidence of infectious hepatitis.

Learning how these impurities affect the public health lies within the field of epidemiology - the study of widespread health problems and hazards and their causes. Epidemiological research concerned with these water quality factors is tedious; the pro-



Organic pollutants extracted from water.



Organic contaminants are recovered by use of carbon filters similar to those shown above.

blem is spread thinly. It requires studying the effects of minute quantities in the water supply on a large population over a long period of time.

Investigation of the epidemiological significance of these new pollution problems has begun in the following ways.

The possible association of soft water and cardiovascular diseases is being investigated with more thoroughness than previous studies. Changes in cities' water supplies because of water softening are being related to mortality rates of the water consumers.

The geographic distribution of infectious hepatitis outbreaks is compared with water quality data to determine if any relationship exists. Possible association between the turbidity of water in certain cities and the occurrence of hepatitis is being investigated.

Data from the National Water Quality Network, which has water sampling stations all over the country, are examined. Reports and data on the occurrence of diseases in areas served by markedly different water quality are analyzed to see if a relationship exists. Carbon adsorption sampling data on organic pollutants and the occurrence of cancer will be analyzed soon.

Supporting work by other research organizations will be arranged as the need arises.

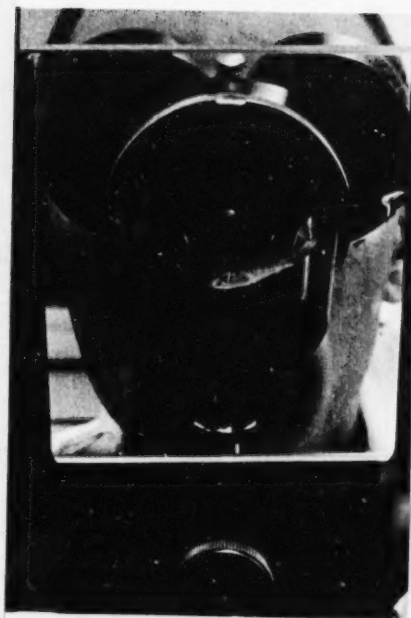
SAFE WATER FOR AQUATIC LIFE

The protection of aquatic organisms through water quality control is of serious economic importance. The fishing industry alone represents an annual income in the billions of dollars. Despite the great commercial and recreational importance of aquatic life, water quality criteria which have been suggested to date are mostly rather crude and protect only a few kinds of water animals. More fundamental knowledge is needed to strengthen practically all existing criteria. More basic research is also necessary for developing new criteria for many water-dwelling animals which have so far been neglected.

The need for effective procedures for developing reliable criteria is immediate. Valid water quality specifications and economical and equitable abatement methods to maintain these and traditional quality standards are urgently required by water pollution control agencies.

At the Center and at a laboratory operated in cooperation with Oregon State University in Corvallis, Oregon, work has begun in the following areas:

TOXICITY. Toxicity tests using fish eggs and fry were started along with studies of the relative toxicity of selected chemicals



Examination for gross external changes.

to the different life stages of fish. Tests for determining tainting in fish flesh have been initiated. Acute and chronic toxicity of selected pollutants to fish and the possibility of using laboratory-raised guppies for waste monitoring bioassays has been examined. Chemical analysis and toxicity studies of pulp mill wastes have begun. Minute tissue diagnostic methods for determining what happens in a fish kill are being developed.

AQUATIC COMMUNITIES. Food habits and reproduction rates of important vertebrates and invertebrates are studied in simple aquatic communities of natural and artificial streams. Dissolved oxygen requirements of fresh water fishes throughout their life history are being determined.

New research will place a great stress on the interrelationship of environmental factors and their effect on the toxicity of introduced wastes.



The Research Branch pilot wing.

TREATMENT OF WASTE FOR DISPOSAL

Waste is actually water which contains added impurities from industries and households. Waste treatment is the processing of these waters to remove the impurities. Typically, cities treat their wastes in the following ways. Primary treatment removes coarse matter by straining and settling. Commonly it is broken down in a digester by anaerobic bacteria. Secondary treatment begins with the effluent from primary treatment and exposes it to microorganisms in the presence of oxygen. The microorganisms use much of the impurities in the water as food and so remove them or make them innocuous. In the trickling filter treatment method the microorganisms grow on a bed of coarse rock and the wastes are trickled over the organisms growing on them. In the activated sludge process drifting colonies of organisms are swept through the wastes while air is pumped into it. The stabilization pond, an old method of renewed interest, retains the waste in a pond where algae which produce oxygen join forces with bacteria in disposing of the waste. The broad new field of advanced waste treatment will use physical

chemistry to go far beyond present waste treatment accomplishment to make the renovated water available for use again.

CATALOGUING MODERN ORGANIC WASTES

Too little is presently known about modern organic wastes to permit treating them effectively in modern waste treatment works. The long range goal of this project is the cataloguing of various members of such chemical wastes according to the degree which they may be broken down by biological sewage treatment processes.

A given chemical waste always will behave in a characteristic manner while under microbial processes, regardless of its associated substances. Therefore the cataloguing of these characteristics of different wastes offers excellent possibilities for an organized system. Such a system would give us the advantage of knowing how effective different waste treatment processes are on a certain waste. With such information a new waste product could be classified on the drawing board and an adequate waste treatment system selected before the substance ever appears as a waste.

Specific wastes are investigated in these aspects: (1) analytical methods to identify and measure the material in water, (2) its microbiological toxicity, (3) its degree of degradation in sewage treatment processes, (4) acclimation of these treatment systems to the material in purification processes and surface water. Controllable factors affecting the waste purification, such as loading rate, temperature, concentration and other factors, also are studied.

Experiments have been made with 3-amino triazole, the weed killer found several years ago in market supplies of cranberries. Examination has shown no significant biochemical degradation of 3-AT in surface water, anaerobic digestion or activated sludge treatment after 150 to 200 days. Activated carbon tests resulted in a 10 to 20 percent removal from water. Following chlorine treatment in doses of 1 to 2 mg per mg of 3-AT in a neutral solution, the chemical could not be recovered.

Research is proceeding on: (1) the extended aeration activated sludge process, (2) surface water persistence and plant treatability of eight vinyls likely to appear in waste water, (3) the anaerobic digestion of the above vinyls, and (4) modified activated sludge operation to increase nitrogen removal.

ADAPTATION OF MICROORGANISMS IN WASTE TREATMENT

Wastes from the organic chemical industries, such as rubber, dye, plastic, petroleum and detergent industries, frequently are unlike anything found in nature. Some of the undesirable materials in

such wastes resist breakdown by microorganisms in waste treatment plants and streams. Not enough is known to forecast the relative resistance of these compounds and their many slight molecular variations. It appears that the biological systems capable of destroying a particular material must change in some subtle ways if they



Phase separation is an important tool of the water analyst .

are to successfully attack a different form of that material.

We must know more about these changes if we are to learn how to predict the resistance of related compounds to microbial degradation. We should learn what conditions govern the adaptation of microbiological systems so that we may permit the systems attack new waste substances efficiently.

Cultures of microorganisms have been adapted to phenol, a prevalent chemical waste, and to a variety of phenolic compounds. The Center has begun studying the efficiencies of these organisms in degrading other phenolic compounds. Future research will isolate species of microorganisms from the total successfully adapted culture and determine which individual strains are the most effective. Primary adaptation of microorganisms to additional types of compounds also will continue.

FUNGI IN ENVIRONMENTAL SANITATION

There is evidence to indicate that some fungi can break down complex organic matter usually considered resistant to attack by most organisms used in sewage treatment processes. Filamentous fungi are present in great numbers in polluted streams, sewage and

treatment systems where wastes are primarily of fecal and kitchen origin. They also are present in soil. As natural organic matter increases, numbers of species and colonies increase to a constant level.

Because of the ubiquitous nature of these fungi, their affinity for organic wastes and the possible role they may play in waste disposal, several questions warrant close examination.

In polluted streams the waste load tends to affect the number of fungi present by increasing individual counts and depressing the number of species. Samples from waste stabilization ponds in Lebanon, Ohio, have been screened by intensive identification procedures to see if this same effect occurs among members of the soil population.

Fungi have been considered aerobic organisms, although large numbers are known to exist in so-called anaerobic systems. To what extent can they be considered as playing a part in reduction of organic wastes in sludge systems? To find the answer, fungus growth is being investigated in the absence of atmospheric oxygen.

Fungi that have indicated an ability to break down complex organic wastes could possibly be put to use in sewage treatment systems. To explore these possibilities the Center is developing techniques to isolate them in pure culture. These techniques will be tested in the field. Studies have been conducted in a Michigan spray disposal bed used for waste sulphite liquor from paper mills to determine if certain groups of cultures may eventually be able to break down lignosulphonic acid, a component in this waste.

TREATING WASTES IN PONDS

No innovation in waste treatment has excited more international interest in recent years than the waste stabilization pond. There are two principal types. The high rate pond detains the wastes five days or less and at present is used primarily in laboratory and pilot plant installations. It provides satisfactory sewage treatment, but can compete economically with the conventional treatment plants only if the algae produced in the system are harvested and sold. The other type, now in use by at least 1000 communities and institutions, has a detention of 30 to 200 days. Its low cost is especially attractive to small communities.

Design of these ponds is presently based on what has been learned by trial and error from existing installations. Too little is known about the influence of solar energy, thermal energy, photosynthesis, total pond respiration, wind and other natural forces. When more is known, these effects can be utilized in deciding the



Sampling liquid in
stabilization pond.

most efficient design of new ponds. Until then construction must continue on an experimental basis.

We need to know more about how pond function is influenced by (1) the rate of sewage introduction and (2) different types of wastes. The public health significance of any widespread use of ponds is undetermined because little is known about the effectiveness of ponds in removing pathogenic organisms, particularly bacteria and viruses. Likewise, the effects of pond effluents on the receiving waterways are poorly understood. A project is presently seeking a scientific basis for the rational design and use of stabilization ponds on a large scale.

A carefully controlled artificial environment in which single natural forces can be varied at will is being considered to measure separate steps in the total pond process. This new information will be a great aid in determining the most efficient and economical pond designs.

Preliminary studies of the destruction of bacteria in sewage have been completed and these results are being compiled. Observations for these studies were made during different seasons at a former SEC facility at Lebanon, Ohio. Laboratory studies are being made on the reaction of algal metabolism to hydrogen sulfide, an objectionable gas sometimes produced by malfunctioning stabilization ponds.

Investigations are underway to determine if treatment efficiency is increased when the wastes are treated in a series of ponds, one after the other. This work and experiments to ascertain the effect of pond overflow on the receiving stream are being conducted at facilities in Fayette, Missouri.

Subsequent research will include development of pond processes which will remove pathogenic bacteria, measurement of the effectiveness of such removals under varying conditions, and identification of the processes involved.

METALS AFFECTING SEWAGE TREATMENT

It is frequently economical to treat the industrial and domestic wastes of a community at one plant. Certain industrial wastes often contain heavy metals, such as chromium, copper, zinc, nickel and cadmium, which are toxic to the microorganisms that do the work in sewage treatment. We need sound knowledge of how these toxic metals affect the efficient removal of organic matter and the digestion of sludge in treatment plants.

This project intends to provide both industries and municipalities with adequate information for them to economically protect

their sewage treatment facilities. Toward this objective, the Center is currently engaged in several investigations in this specific area.

Studies have been made to determine the effect of chromium and of copper on the efficiency of biological treatment processes. Analytical methods for detecting these metals in treatment plant sludges and effluents have been developed and tested. The toxic effects and tolerable levels of nickel, zinc and cadmium will be ascertained.

ADVANCED WASTE TREATMENT

Only so much water is available to the earth's inhabitants. The growing needs of our expanding population and industry require that water be used over and over. Contamination of surface and groundwaters by industrial and municipal wastes is increasing. Synthetic detergents, pesticides, petrochemicals and various inorganics are examples of contaminants which are not adequately removed by conventional water treatment methods and natural stream processes. These persistent wastes have appeared in drinking water supplies. The health effect of many of them is unknown.

The Advanced Waste Treatment Program was established in 1960 to develop better methods of removing resistant wastes. The goals of the project are twofold: to treat wastes effectively and to produce reuseable water. A very substantial part of the problem is the destruction or the ultimate disposal of the waste products removed.

Removal of resistant wastes based on physical-chemical principles are being studied under a coordinated program of intramural research and negotiated research contracts with non-governmental agencies. As part of this study, the program is seeking new ways of using industrial processes not presently used in waste treatment.

These are some of the processes already under study.

ABSORPTION. The phenomenal ability of activated carbon to adsorb organic contaminants is well known. The problem is to reduce the cost of applying this technique by making carbon reuseable. Other cheap, easily obtainable adsorbents also are being examined.

FOAMING. The foaming of waste water at sewage plants has been a widespread nuisance. However, detergents and other surface active contaminants concentrating in these foams suggest that this phenomenon, usually a hindrance, may be deliberately used in the future to remove certain impurities.

OXIDATION. If hard to remove contaminants could be destroyed by oxidation, the organic waste disposal problem would be solved. Experiments with strong oxidizing agents such as chlorine, chlorine dioxide, ozone, peroxide and others have begun at the Center.

ELECTROCHEMICAL METHODS. One way to purify waste water would be to electrolyze it into hydrogen and oxygen and recombine these elements into pure, new water. At present this process of actually recreating water would be a costly process; however, it may be possible to reform the water in a fuel cell where electricity is produced very efficiently along with the new water. This electricity could be used to perform part of the original electrolysis, thus reducing the operating cost.

Such techniques as electrodialysis, distillation and freezing are being studied by the Advanced Waste Treatment Program. To be feasible, the degree of waste concentration will have to be very high to reduce the bulk of separated impurities to a minimum. This would permit cheaper disposal of these waste materials or facilitate economic recovery of valuable products.

DEVELOPING SMALL SEWAGE TREATMENT UNITS

Small, simple and dependable disposal plants are needed for rural housing developments, schools, restaurants and small industries where it is not possible to treat the wastes in municipal plants.

An anaerobic process was used by the Center to treat wastes from housing developments with 200 to 400 homes and was found satisfactory as to primary treatment device. The process combines an anaerobic digester and a settling tank in one unit. Raw sewage is introduced into the bottom of the tank beneath a blanket of biologically active sludge. As the sewage moves upward, solids simultaneously settle and are digested by the sludge.

Recently, aerobic systems, similar to the municipal type, have been adapted for small installations. The Engineering Experiment Station at Ohio State University is under contract to the Center to develop a small efficient disposal unit using the anaerobic and aerobic processes in series. The goal is an effluent pure enough for direct discharge to ground or streams without polluting them.

A unit using these processes was tested for 16 months and showed the ability to reduce BOD 90 per cent and suspended solids 92 per cent.

DISPOSAL OF WASTE EFFLUENTS

Modern treatment methods do not remove all contaminants. The environmental significance of the residual components in waste effluents must be determined to avoid pollution of all of our water resources from this source. Although most of the nation's needs are met by surface water, there is much more water flowing underground than there is in fresh water lakes and reservoirs above the ground. Commonly in the past the ground water resource has been pure because many of the impurities in surface water were removed by soil particles as the surface water percolated downward into the underground stream or aquifer. Now wastes are being discharged directly into the soil and are polluting ground water. Some new chemical products, such as the active ingredient in detergents, are not well removed by conventional waste treatment, persist in surface waters, and pass through modern water treatment. To allay these pollutional threats, we must learn how to best use surface waters for dilution of waste after treatment and how to dispose of wastes in soil without ruining ground waters.

LIQUID WASTES IN SOIL

Some 15,000,000 households and a large number of communities and industries use surface or underground soil absorption systems for the disposal of wastes. Properly used, soil absorption units, such as cesspools and septic tanks, can be safe and economical. They can aid water conservation by reducing the waste load on surface waters and permitting the wastes to be used for irrigation and recharging underground waters. However, improper use of the soil for waste disposal may result in gross nuisances, health hazards and impaired land.

The technology of waste treatment for disposal to surface waters is well developed, but disposal to soil has received far less attention. Under the sponsorship of the Federal Housing Administration, research at the Center has given insight into the use of soil for the disposal of household wastes. Three similar basic programs have begun at the Center under Public Health Service auspices in these areas: (1) the mechanism of soil clogging when wastes are applied, (2) the relationship between soil and waste properties and clogging rates and (3) the persistence and underground travel of pollutants.

The ultimate objective of these and associated studies is the development of rational procedures for design of effective and economical waste disposal systems.

Several specific investigations within the aforementioned categories are now underway. A hypothesis, predicting the course of waste clogging of the soil, is being examined using membranes of known pore size and structure to simulate soil. The clogging rates are being observed using a common waste of known characteristics. The hypothesis, developed as a result of FHA project field studies is being tested in these experiments. The investigations have been followed up by laboratory soil column tests measuring the effect of various wastes on different soils.

A field study site will be established in the Cincinnati area to evaluate the effects of uncontrollable environmental factors, such as evaporation and temperature, on the soil's waste absorption capacity. Instruments will be placed directly in the ground to measure the effects on natural soils under natural conditions.

MONITORING WASTES IN STREAMS

Drinking water should be safe, odor free, clear and palatable. Other water uses have different, sometimes more exacting, requirements. To protect quality we must effectively monitor our water resources. There are three important phases to monitoring: selection of criteria which accurately measure water quality of a given stream; collecting desired information, and interpreting it correctly. Some wastes can be detected fairly well. By sampling and analytical techniques for coliform and streptococcus organisms fecal pollution in water can be discerned. The Center has developed equipment for the continuous measurement of dissolved oxygen, a significant advance in detecting and recording the effects of oxygen demanding wastes. More is being learned about the detection of stable organic industrial wastes with the carbon adsorption method of sampling, also developed at the Center. Work is progressing to make use of aquatic life as indicators of pollution. Research to improve monitoring procedures will continue so that data collected will truly reflect water quality.

BACTERIAL INDICATORS OF POLLUTION

A bacterial species or group may have great sanitary significance if it is an organism always found in human or animal wastes, is always found where enteric pathogenic bacteria are present and is absent only when enteric pathogenic bacteria are absent. Such a species or group would be an ideal indicator of pollution. There are several bacterial groups which have been used classically as pollution indicators.

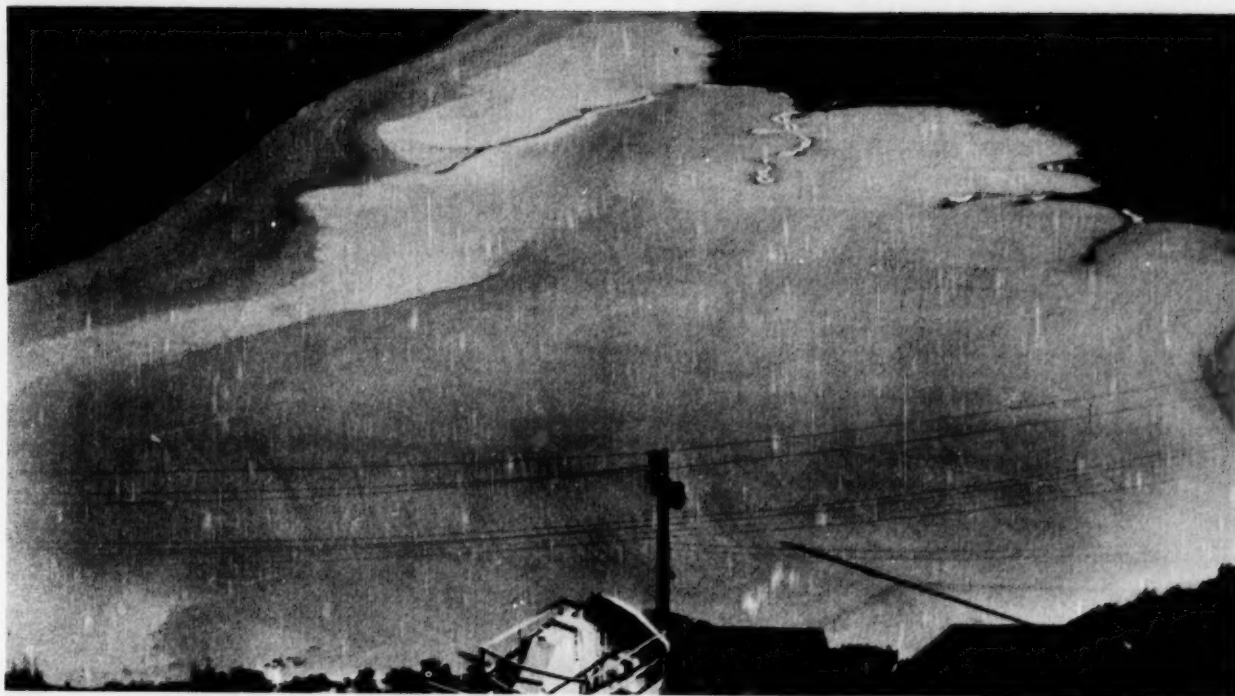
The main goal of this research project is: (1) the perfection of simpler methods of using the proven indicators, (2) the examination and development of newer, surer indicator procedures and (3) interpretation of their significance to water safety. The achievement of new test methods and the improvement of old would be a great step forward in pollution detection and control.

One improved test using fecal coliform bacteria as an index of pollution has been developed at the Center. This test is based on the gas production by the bacteria at a temperature a little above body heat during 24 hours. It was developed to take the place of four biochemical-reaction tests (IMVic) requiring five days. It has proven to be an excellent indicator and additional statistical evaluation of the reliability of this procedure is being completed.

Investigations of the streptococcal group of bacteria have indicated they may serve in some specific conditions as even better



Using bacteria to measure water quality.



Wastes released into lakes and streams range from the obvious to unseen quantities of subtle chemicals. Shown above is waste from an industrial plant.

indicators than the coliform group. Like the coliforms, they are constantly found in the intestines of warm blooded animals. Unlike the coliforms they are reported not to reproduce once they are in the polluted stream. Because no "overgrowth" occurs in the stream, the streptococcal group may be a better indicator of the fecal wastes present.

Work is underway to simplify identification of the promising species of streptococci and to interpret their presence.

An examination of streptococcal and coliform groups in cold blooded animals is being enlarged to include fish in clean and polluted streams. These tests will determine if indicator organisms can originate from fish living in the stream as well as from the waste of warm blooded animals which have been introduced into the stream. The possibility of fish serving as collection devices for indicator organisms in the streams also will be examined.

Still other groups of bacteria show evidence they may be used to measure steam pollution from different sources. For example, one species of bacteria (*Lactobacillus bifidus* subtype B) is alleged to be present only in human feces, and so might be a specific indicator of human pollution. It is hoped an enumeration procedure for this organism can be developed. Research on this and other possible indicator bacteria will be pursued to determine what

species or groups may be valuable pollution indicators. More intensive data on the growth, survival or die-off of these indicators in surface waters will be gathered.

The search for new indicator organisms should be fertile. Traditional indicator organisms represent only a small minority of the total bacterial flora in excreta and many unknown species may be potentially useful as indicators of fecal pollution.

The usefulness and reliability of traditional indicator organisms has been proven and the development of new, more efficient biochemical pollution tests seems assured. However, the best indicator is still only an indirect determination of the presence of disease producing organisms, regardless of its reliability. Work will begin which may yield quantitative enumeration of a pathogenic organism (Salmonella) from polluted waters. If this research is successful it would produce a test for pollution based directly on the presence of pathogenic organisms present in the water. Due to the time required for the tests, the water would be consumed before the pathogenic bacteria were identified and so would not be used as a preventive test. Such a test would, however, be extremely useful in disease studies and in estimating the probable hazard of polluted water sources.

PINPOINTING ORGANIC CONTAMINANTS

Previous mention has been made of the growing problem of new organic wastes appearing in the country's water resources. Our knowledge of these contaminants is sparse. The general goal of this project is the development of better ways to identify, measure, and evaluate the polluting effects of these contaminants.

A large scale activated carbon sampling system developed at the Center has been used to gather organic contaminants for extensive tests including examinations of the carcinogenicity (cancer producing properties) and toxicity of various pollutants.

Studies have been made to advance the fundamental understanding of the phenomena of adsorption, the process generally used in collecting pollutants. Concentration of contaminants by evaporation under vacuum and by ion exchange has been studied. Polynuclear hydrocarbons, pollutants of recent interest, are common as minute constituents of many organic wastes, including those from oil refineries and petrochemical plants. Procedures for collecting and analyzing them have advanced to a point where a standardized procedure for stream monitoring is in sight. Detergent analysis studies have been expanded.

Much progress has been made using gas chromatographic separation techniques in combination with infrared spectroscopic analysis techniques. The combined procedure has yielded con-

taminant identifications not otherwise possible, especially in the field of petrochemical wastes.

Subjects have been recruited for odor tests of various contaminants in water and their reactions compiled according to standardized procedures. These investigations have produced impressive validation to the laboratory-derived conclusion that odor effects of multiple wastes may be cumulative.

Toxicity and other physiological testing with mammals is being continued to include the effects of extended exposures to more varied organic wastes. Gas chromatographic separation techniques are being expanded and intensified. New work will include attempts at tracing contaminants to their points of origin and identifying contaminants directly from water samples, without involved intermediary procedures.

The possibility that a single test technique, flame ionization, may be developed to detect all the organic wastes in a water sample will be investigated. Analysis methods for polynuclear hydrocarbons will be perfected. These methods, along with others, will be used in a wide survey of the potential health threat of this group of water pollutants.

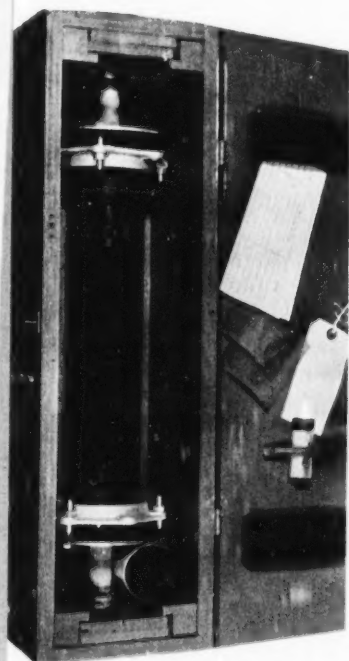
WATER AND VIRAL DISEASES

The measurement of coliform bacteria has been the accepted criterion of water quality for many years. This index is not always able to indicate a newly recognized group of about 70 viruses which are present in sewage and infect man. Little is known about the survival of viruses in the environment or their resistance to chemical and physical agents traditionally used in purification. We must reevaluate the usefulness of the coliform and fecal streptococcal indices and determine if they still adequately indicate unfit water.

The increasing use of stabilization ponds for sewage treatment and the use of treated sewage effluents to recharge ground waters make it desirable to determine how effectively these methods remove viruses and how such removal is accomplished.

Water, as a carrier of infectious hepatitis, is among the major problems in virology today. To study such viruses immense volumes of water would need to be examined, but there are no good methods for doing this. The development of techniques for concentration, detection and enumeration of small quantities of viruses in water is another pressing need.

The survival rates of certain enteroviruses in several types of water are being compared with the survival rates of several



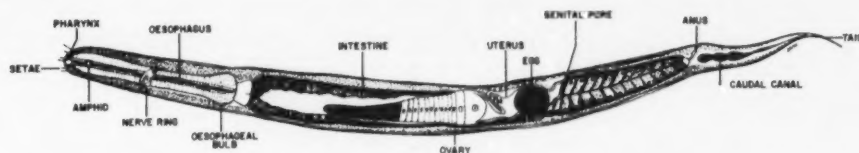
A carbon filter packed for shipment.

water quality indicator organisms. The effectiveness of filtration through various sands and soils as a method of removing viruses from water and sewage is being studied. The efficiency of employing electromotive forces (electrophoresis) in concentrating viruses in dilute suspension is being determined. Concentration of viruses by adsorption on water-suspended monkey kidney cells also is being investigated. Practical methods of viral concentration by diffuse cell adsorption and electrophoresis will be developed if these techniques prove promising. Potentially suitable media for growing the virus of infectious hepatitis for research will be studied.

MINUTE ANIMALS IN WATER SUPPLIES

A recent survey by the Center has shown the extensive presence of free-living nematodes (minute nonparasitic roundworms) and a lesser degree of free-living amoebas in municipal water supplies served by modern treatment facilities. These organisms are especially prevalent in water supplies taken from rivers with some sewage pollution. Remarkably, these organisms were found in a viable state.

MONHYSTERA (Female)



A female nematode (Monhyстера).

Previous studies have also shown that nematodes taken from water supplies are also present in large numbers in the effluent of aerobic treatment processes. In the laboratory these worms have shown the ability to ingest pathogenic bacteria and viruses (Salmonella, Shigella and Coxsackie virus) and to protect them from chlorine used in water purification processes. Small free-living amoebas also are known to ingest pathogenic bacteria but are considered not to be carriers. Nematodes have long been found in slow sand filters where their gummy secretions have been suspected in taste and odor problems.

TREATMENT OF WATER FOR REUSE

Most of the water consumed by urban populations is purified by physical and chemical treatment methods. Classically, this process begins by letting the raw water stand so that the larger particles like mud and clay can settle out. Finer particles and suspended material are removed by adding a chemical coagulant which unites with the particles to form larger masses called flocs. These feathery precipitates are removed by settling which also removes microorganisms and other particles caught up in the flocs. Subsequent filtering, usually through sand or other porous material, removes residue floc and other fine particles and organisms also. Where necessary, aerating the water removes a lot of the odorous gases that may be trapped in the water. Disinfection, usually with chlorine, kills most living organisms. These conventional purification methods have been successful for many years, but improved methods are needed to meet the challenge of new dissolved pollutants and intensified water use.

Obviously, it is of great importance hygienically to examine the distribution and significance of these organisms. Sewage effluents from aerobic treatment plants are being surveyed for free-living nematodes and the nematodes found are examined for human enteric pathogens. The pathogens found will be isolated and identified. Culture methods are being developed for producing large populations of nematodes in the laboratory. These populations are used to measure the resistance of nematodes to various disinfectants and antinematodal agents.

IMPROVING WATER TREATMENT

The basic methods of municipal water treatment have not changed substantially for almost 50 years. Many improvements could be made. To do this we must first understand the roles of the various processes and their relative efficiency. Initial research in these areas has been concentrated on the allied water treatment processes of filtration and coagulation.

Pilot plants at the Center have been used to study filter design and operation with and without pretreatment of the water. The functions of the filter medium, and the influence of its size and shape, the porosity and depth of the filter bed and the rate of flow through the filter have been investigated. The effect of these factors on the removal of various sizes and types of particulates, such as algae, bacteria, viruses, protozoan cysts and mineral particulates, is being determined. The role of filtration in removing

very small motile animals, such as worms and insect larvae, also will be examined.

Cooperative studies of high rate filtration methods have been conducted with the City of Gaffney, South Carolina and the South Carolina State Board of Health.

Because of the relationship between filtration and flocculation, it is necessary to understand the properties of flocs and the factors which may affect these properties. The Center hopes to develop an instrument to measure the force which holds these masses together. This would be a great aid in determining how these precipitates can be best prepared for removal by filtering.

The dose of coagulant necessary to precipitate the particulates from a specific batch of water is now arrived at in a water treatment plant by trial and error. More basic knowledge is needed to provide a sounder technical approach to coagulant dosage. Further studies will be focused on the fundamental factors affecting the coagulant demand of water.

CONTROL OF NUISANCE ALGAE

Surface waters commonly support growths that affect water utilization. Algae are a nuisance in recreational waters, impart tastes, odors and visible materials to industrial and domestic supplies, change the physical and chemical composition of the water and interfere with purification and distribution. The examination of these problems and the development of control methods is the long range goal of this research project.

The possibility of using actinomycetes, the antibiotic producing bacteria, and fungi as sources of algicides has been investigated. Attempts will be made to isolate the specific antialgal substances from these sources. The extent and control of odor and taste production by actinomycetes in water supplies is being reinvestigated.

Work will continue on the development of improved ways to evaluate the effect of plankton populations on water treatment.

Better, more comprehensive ways for determining the algicidal properties of various chemical compounds will be sought. Tests will be made to determine the amount of algicide necessary to control various concentrations of algal material.

Literature on algae and other interference organisms of importance have been completed for Indiana, New England, Chesapeake area, South Central States, California and Ohio. A review for a seventh area of the United States, the Northwest, is in progress.

Use of membrane filters as a detection device for algae will be tested. This technique would provide a valuable method of testing for algae in treated water supplies. Investigation of the algae causing problems in recreational waters also will be made.



Growing organisms suspected of causing tastes and odors in water.

CONTROLLING NUISANCE SLIME ORGANISMS

Bacteria which use or accumulate sulphur compounds in their metabolic processes may produce slime and mucous masses which are a clogging nuisance in a great many water handling systems. They also give water an unsightly appearance, unpleasant taste and odors, contribute to the loss of chlorine used in water purification, and may protect pathogenic and nonpathogenic bacteria. Little is known about their cultivation, enumeration and identification.

The lack of adequate methods for cultivating nuisance organisms in the laboratory has seriously hampered their investigation. Studies to improve the cultivation of these organisms in culture media have been conducted. The best source of available iron bacteria and other nutritional components must be determined to aid in the investigation and cultivation of the nuisance bacteria. Such a study will give insight into the factors affecting their growth activities and in estimating their densities.

The relationship of iron bacteria to oxidation and precipitation of manganese will be investigated. Continuous flow units and activated sludge units will be used to grow nuisance organisms for study. Methods will be developed to stimulate streams, filter galleries of water treatment plants and cooling units of industrial plants in the laboratory. The effects of aeration, flow rate, oxidation-reduction potentials and recycling the liquid through the units will be studied on the mock-up facilities. The results of these tests should provide valuable information for dealing with slime nuisances in actual situations.

The occurrence of another slime producing species (Sphaerotilus) is one of the most objectionable products of stream pollution. This species fouls fish nets, clogs irrigation ditches, reduces stream flow, causes bad odors, looks unsightly and is a general nuisance. It occurs with pollution from many kinds of waste. This species also has an ability to grow profusely under widely diversified conditions of food supply, temperature and location.

In the investigations of the Sphaerotilus group, the flow rates and food concentrations appear to be a critical item in its growth and structure, and consequently in its damaging effects. Experiments similar to those for the iron and sulphur bacteria are being run on the Sphaerotilus group.

WATER PASTEURIZER

This project has developed a simple, reliable and economical method of treating water from farm ponds or similar sources for use as a domestic water supply. The unit treats the water by pas-



An algal bloom.

teurization and is capable of treating 250 gallons in 12 hours. This should be adequate for a normal family of five with a 100 per cent excess capacity for greater than average demand.

The heart of the unit is a heat exchanger which recovers all but 10 degrees F. of the heat required for treatment and allows pasteurization at 161 degrees F. for 15 seconds with reasonable power input.

The unit avoids many of the disadvantages of chemical water purification. It is automatic and requires very little maintenance. The total cost of treating water by this process is on the order of one dollar per 1000 gallons.

Water purified by this unit has proved hygienically satisfactory even when the untreated water contained a very high bacterial concentration.

DISINFECTING EFFECTS OF SILVER

Recently there has been a renewed interest in the use of silver as a disinfectant, particularly for small water supplies where conventional treatment is inconvenient or impractical. Some of the recently proposed silver treatment systems were reported to be relatively inexpensive, require little maintenance, leave no bad tastes or odors in the water and to destroy bacteria of intestinal origin.

As a first step the Center improved the procedures for chemical and bacteriological evaluation of the effectiveness of silver disinfectants. Several unusual problems had to be solved. For example, it was found that half of a test silver concentration may be adsorbed by laboratory glassware. Further, the lack of a satisfactory neutralizer for the silver resulted in bacteriostasis which could be mistaken for disinfection. Sodium thioglycollate proved successful as a silver neutralizer. It was shown that silver is more active as a disinfectant at higher temperatures than at temperatures around freezing and more active in alkaline than in acid solutions.

Because of its relative expense, adsorption and bacteriostasis characteristics, long reaction time and other factors, it was generally concluded that silver would not be a very useful disinfectant in large applications. However, these characteristics might be useful in specific, small applications.

SUPPLEMENTATION AND CONSERVATION OF WATER

A most direct means of preserving the Nation's water resource would be to reduce water loss. Evaporation alone accounts for a loss from U. S. reservoirs exceeding 23 billion gallons per day. One experiment, spearheaded by the Bureau of Reclamation, cut this loss by about nine per cent under adverse conditions on a 25,000-acre western lake. The use of porous underground strata as vast water storage reservoirs may be another significant conservation aid of the future. There is much to be learned. Sometimes water released from reservoirs is detrimental to the stream because of oxygen loss and other chemical changes in the water during storage. Ground water resources need to be protected from wastes discharged into the ground from homes, cities and industries. The close relationship between the quality and the quantity of water, emphasizing the need for conservation, was dramatically pointed up recently during a severe drought in the midwest. At one city, where the water was reused several times after extended treatment, drinking water came from the tap with a beer-like color and had a detergent foam.

REDUCING EVAPORATION LOSS OF WATER

The possibility of floating a solid film a single molecule thick on the surface of a reservoir to reduce evaporation loss has excited considerable interest. A large scale test conducted by the U. S. Bureau of Reclamation at Lake Hefner, Oklahoma showed that even under unfavorable conditions evaporation savings justified the cost of the operation. The Center has worked closely with the Bureau, especially in evaluating the significance of the biological breakdown of the film-producing material.

The type of microbes which attack the evaporation suppressing compounds, the manner of attack and means of combating such an attack are of primary interest to this research project.

In order to quickly measure the efficiency of monolayer films, the Center developed a sensitive photoelectric evaporation detector and used it successfully in a large number of experiments. This instrument is being improved.

Studies have been initiated to determine the life span of monolayer films of various compounds in the presence of bacteria known to attack them and to ascertain the film breakdown mechanism of such bacteria.



Learning to protect evaporation suppressing compounds from bacterial decay.

Studies are being made to evaluate various antibacterial compounds for their effectiveness in increasing the life span of monolayer films, thus lowering the cost of evaporation reduction. Other film-producing compounds are being examined for inherent resistance to bacterial attack.

PERSISTENT GROUND WATER POLLUTANTS

Serious incidents of ground water pollution have increased in recent years. Still greater hazards are being created with the increasing use of soil absorption systems, storage lagoons, oxidation ponds, spray irrigation systems and grassland filters as methods of disposing of domestic and industrial wastes. This kind of pollution is particularly insidious because of the slow travel of ground water. Extensive damage may occur to the water resource before it is noticed and such damage may persist for years after the pollution has stopped.

These problems often have been neglected simply because not enough is known about organic ground water pollutants to enable state agencies to recognize potentially damaging situations. What little information is available indicates that some organic waste materials which are readily broken down in surface waters persist for a long time in underground water resources.

This project seeks to establish safe disposal practices for organic ground water pollutants. To do this, biological, chemical and physical processes by which these wastes are degraded in the soil and ground water aquifers must be better understood.

Carrying out this research, the Center has: (1) conducted pilot plant studies on the movement of alkyl benzene sulfonate (ABS) which showed that bacterial degradation of ABS in the saturated zone is insignificant and further that ABS does not affect the rate of bacterial travel, and (2) completed a review of the technical literature and unpublished information on ground water pollution. A National Symposium on Ground Water Contamination brought together experts in the field in April 1961.

Studies have been initiated on: (1) the behavior of ABS in the unsaturated zone above ground water tables where the chances of bacterial degradation are greater, and (2) the relative physical and chemical processes in the extremely slow removal of ABS in the soil.

These studies will be extended to new, important organic substances which may appear in the ground water resource.

MAN-YEARS OF PROFESSIONAL EFFORT IN RESEARCH ON PROBLEM AREA

	<u>Fiscal Year Initiated</u>	<u>Total Through FY 1961</u>	<u>Effort during the Biennium</u>
<u>WASTE CHARACTERIZATION</u>			
Forecasting the effects of new pollutants.	1958	5	4
The health threat of impure water	1961	1	1
Safe water for aquatic life	1953	33.5	10
Physical and chemical phenomena affecting water quality (temporarily deferred)	1958	0.5	0.4
<u>TREATMENT OF WASTE FOR DISPOSAL</u>			
Cataloguing modern organic wastes	1950	25	4
Adaptation of microorganisms in waste treatment	1957	8.8	4
Fungi in environmental sanitation	1951	19	4
Treating wastes in ponds	1955	10	2
Metals affecting sewage treatment	1957	14.4	5
Advanced waste treatment	1961	4	4
Developing small sewage treatment units	1956	10	3
<u>DISPOSAL OF WASTE EFFLUENTS</u>			
Liquid wastes in soil*	1957	32.8	8

* Cooperative project for FHA

	<u>Fiscal Year Initiated</u>	<u>Total Through FY 1961</u>	<u>Effort during the Biennium</u>
<u>MONITORING WASTES IN STREAMS</u>			
Bacterial indicators of pollution	1955	25.6	6
Pinpointing organic contaminants	1949	43	5
Water and viral diseases	1954	25	4
Minute animals in water supplies	1958	2.8	1
Effect of chlorine on indicator bacteria	1958	5	2
Serological identification of waste components*	1957	11	4
<u>TREATMENT OF WATER FOR REUSE</u>			
Improving water treatment	1954	12.5	5
Control of nuisance algae	1950	28.5	4
Controlling nuisance slime organisms	1961	1	1
Water pasteurizer	1956	5.5	0.5
Disinfecting effects of silver	1958	4.4	0.4
Removal of coliform organisms	1954	4	0.5
<u>SUPPLEMENTATION AND CONSERVATION OF WATER</u>			
Reducing evaporation loss of water**	1961	1	1
Persistent ground water pollutants	1955	4.0	2.5

*Cooperative project for A. C. C.

**Cooperative project for Bureau of Reclamation

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